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RESEARCH MEMORANDUM

PRELIMINARY INVESTIGATION OF A TRANSLATING COWL TECHNIQUE FOR IMPROVING TAKE-OFF PERFORMANCE OF A SHARP-LIP SUPERSONIC DIFFUSER

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SUMMARY

A preliminary investigation was conducted in quiescent air on a translating cowl technique for improving the take-off performance of a sharp-lip supersonic diffuser. The technique consists in cutting the cowling in a plane normal to its axis and then translating the fore-part of the cowling in the forward direction, thus creating an auxiliary annular inlet and increasing the minimum geometric throat area. Efficient intake of air through this auxiliary area at take-off is obtained by providing the fixed portion of the cowling with a rounded lip. Appreciably improved inlet performance in terms of pressure recovery and mass-flow characteristics was obtainable with a cowling translation corresponding to a gap of only 1/4 inlet radius.

INTRODUCTION

In designing an air inlet to be used in conjunction with a turbojet engine, consideration must be given to matching the inlet geometry to the mass-flow requirements of the engine. As a result of such considerations, the inlet size required for the take-off condition normally exceeds those sizes required throughout the subsonic and low supersonic Mach number range. In the supersonic range, the fact that the inlet has a larger projected area than the required capture stream tube of air entails spillage of air with accompanying "additive drag" penalties. Thus reduction of the inlet size required for take-off is desirable for supersonic flight.

One method that has been used previously to reduce the required inlet size is the use of "blow-in" doors which provide supplementary inlet area for the take-off condition and which close when this extra area is no longer needed. The use of such devices permits the inlet to be sized for the supersonic design Mach number.

If blunt or rounded lips are used on the cowling, the inlet can be made fairly efficient at take-off and the auxiliary inlet area can be kept to a minimum. However, a blunt-lip inlet at supersonic speeds may cause excessive additive drag penalties in comparison with a properly sized sharp-lip inlet. Unfortunately, a sharp lip aggravates the take-off problem because its inherently poor performance at large inlet velocity ratios requires a large auxiliary inlet area. 2318

A preliminary investigation was conducted at the NACA Lewis laboratory of a "translating cowl" technique which permits the use of a sharp-lip inlet for supersonic speeds and provides a convenient means of obtaining efficient auxiliary inlet area for take-off. The technique consists in cutting the cowling in a plane normal to the axis and then translating the forepart of the cowling in the forward direction thus creating an auxiliary annular inlet area and increasing the minimum geometric throat area. Efficient intake of air through this auxiliary area at take-off is obtained by providing the fixed portion of the cowling with a rounded lip. The investigation was conducted on a half-conical-spike side-inlet model. The manner of cutting the cowling as well as the location of the cut were arbitrarily chosen and are not suggested to represent optimums but merely to demonstrate the effectiveness of the technique. Only the case of zero forward velocity was considered.

The translating cowl technique also theoretically shows some promise as a method of inlet-mass-flow variation at supersonic speeds. In such an application the break in the cowling would be contoured to provide a variable convergent nozzle directed downstream when the cowling is nearly completely retracted.

SYMBOLS

The following symbols are used in this report:

A cross-sectional area of subsonic diffuser

A_T geometric throat area

R cowling radius at inlet lip

r cowling-surface radius

x axial distance measured from sharp cowling lip in retracted position

L length of gap between translating and fixed portions of cowling

M Mach number

P total pressure

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m actual mass flow through the inlet

m* theoretical maximum mass flow. Cowl retracted.

Subscripts:

1 station in quiescent air upstream of inlet

2 station 1/2 duct diameter downstream of subsonic diffuser exit

APPARATUS AND PROCEDURE

The translating cowl technique was investigated with the side-inlet model of reference 1. This inlet utilized a supersonic diffuser consisting of half of a 50° conical spike inlet mounted on a flat plate. A photograph of the unmodified model is shown in figure 1. In addition, the internal contours and some significant dimensions are presented in figure 2.

The original inlet model was modified by cutting the cowling in a plane normal to the inlet axis 0.88 inlet radius (1.32 in.) downstream of the sharp-inlet lip. Details of this modification are shown in figure 3 (as well as a sketch of a possible contour for use as a bypass, which will be discussed later). The leading edge of the fixed portion of the cowling was rounded in a somewhat arbitrary manner. No developmental work was done on the shape of the rounded lip although careful attention to this design detail is probably desirable in application. The forward or translating portion of the cowling had a blunt trailing edge for ease of fabrication. In quiescent air this detail probably had no appreciable detrimental effects except perhaps with the smallest gap settings. A photograph of the modified inlet with a gap of 1/4 inlet radius is shown in figure 4.

Moving the cowling forward yields approximately an 18 percent increase in minimum geometric throat area (figs. 2(b) and 3). A larger increase is readily obtainable if the break in the cowling is located further downstream.

The investigation was conducted by connecting the discharge of the diffuser to an exhauster system. Lowering the discharge pressure increased the mass flow into the inlet to the maximum choking value, which was done for the original inlet and for the modified inlet with values of the cowl-position parameter L/R of 1/8, 1/4, 1/2, and 1. The length of the gap with the cowling in a forward position is represented by L, and R is defined as the cowling radius at the sharp inlet lip (fig. 3). The inlet conditions were atmospheric.

The 40-tube pitot-static rake of reference 1 was located 1/2 duct diameter downstream of the exit of the subsonic diffuser as indicated in figure 2(a) to determine the inlet total-pressure recovery and flow distribution. The subsonic portion of the diffuser discharged into a section of pipe containing a standard A.S.M.E. orifice plate, which was used to measure the inlet mass flow. 2318

DISCUSSION OF RESULTS

The performance of the translating cowl inlet in quiescent air is presented in figure 5 in which inlet total-pressure recovery P_2/P_1 is plotted as a function of inlet mass-flow ratio m/m^* for the range of gap settings. The average total pressure at the discharge of the subsonic diffuser (station 2) is represented by P_2 and P_1 is the ambient total pressure, which was atmospheric. The actual mass flow through the inlet is represented by m and m^* is the theoretical maximum (choking) mass flow possible through the minimum geometric throat of the inlet with the cowl completely retracted (that is, original unmodified inlet).

The unmodified inlet $(L/R = 0)$ exhibited rather poor performance in quiescent air as originally indicated in reference 1. As the mass-flow ratio, and hence the dynamic pressure at the throat, was increased, the inlet total-pressure recovery decreased rapidly reaching a value of 0.90 at a mass-flow ratio of slightly more than 0.5 and a value of less than 0.70 as the maximum mass flow was attained. The maximum mass-flow ratio was only 0.79, probably as a result of an internal vena contracta resulting from separation at the sharp lip.

The modified inlet exhibited greatly improved performance for relatively small forward travel of the cowl. At a cowl-position parameter L/R of 1/4, the pressure recovery did not drop below 0.90 until a mass-flow ratio of 0.87 was reached, and was 0.83 at the maximum mass-flow ratio of 1.03. Further increases in L/R resulted in only small improvements in the inlet performance.

At a given mass-flow ratio, the improved pressure recovery with the translating cowl resulted from two related causes. The geometric throat area was increased and hence the throat velocity and dynamic pressure were decreased with corresponding reduction in diffuser losses. The increase in throat area was magnified since the rounded lip provided for a decreased vena contracta and improved flow at the start of the subsonic diffuser. This favorable effect is illustrated by the fact that with the cowl forward, the maximum mass flow obtainable was approximately 90 percent of that theoretically possible through the new geometric throat.

Careful attention to details in the design of the rounded lip would probably improve this performance.

At certain settings of the cowling the inlet exhibited a piercing whistle.

CONCLUDING REMARKS

Performance of the translating cowl at low subsonic velocities before retraction of the cowl remains undetermined. Performance of the inlet at low subsonic velocities after retraction of the cowling may be estimated from reference 2 in which sharp-lip supersonic diffusers are investigated under those operating conditions.

The translating cowl feature may also be useful as a means of varying the inlet mass flow for off-design operation at supersonic speeds. The inserted sketch in figure 3 indicates the manner in which this variation might be accomplished. The break at the juncture of the fixed and translating portions of the cowling would be contoured so as to form a variable convergent nozzle directed downstream with the cowl in a nearly retracted position. With reasonable pressure recovery and nozzle efficiency, this method of mass-flow variation may be comparable to spilling the mass flow upstream of the inlet by means of an oblique shock wave. Experimental verification of this possibility is required.

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REFERENCES

1. Goelzer, H. Fred, and Cortright, Edgar M., Jr.: Investigation at Mach Number 1.88 of Half of a Conical-Spike Diffuser Mounted as a Side Inlet With Boundary-Layer Control. NACA RM E51G06, 1951.

2. Dennard, John S.: An Investigation of the Low-Speed Characteristics of Two Sharp-Edge Supersonic Inlets Designed for Essentially External Supersonic Compression. NACA RM L7D03, 1947.

Figure 1. - Unmodified side-inlet model mounted on flat plate.

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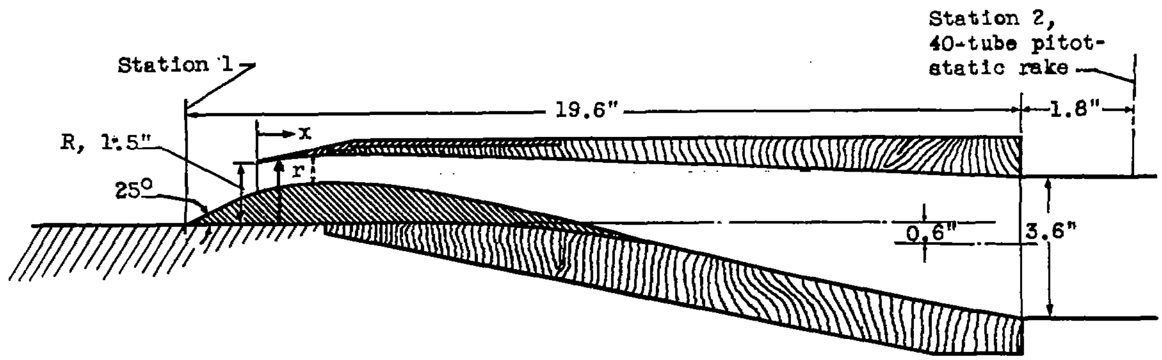
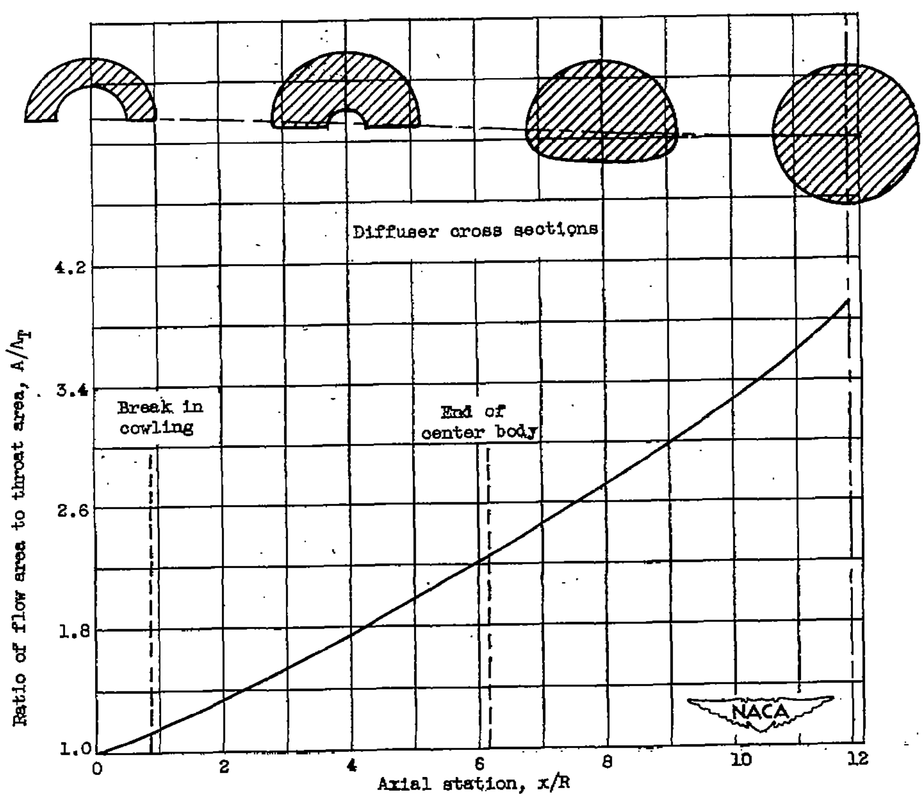
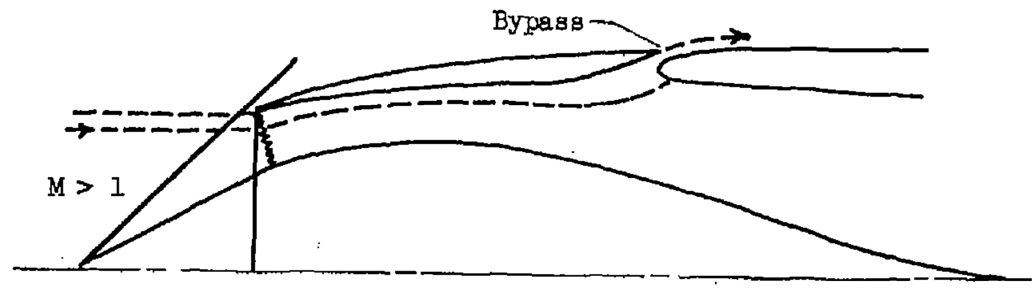


(a) Model dimensions.



(b) Internal area variation.

Figure 2. - Model dimensions and cross-sectional area variations of side-inlet configuration.



Mass-flow bypass application

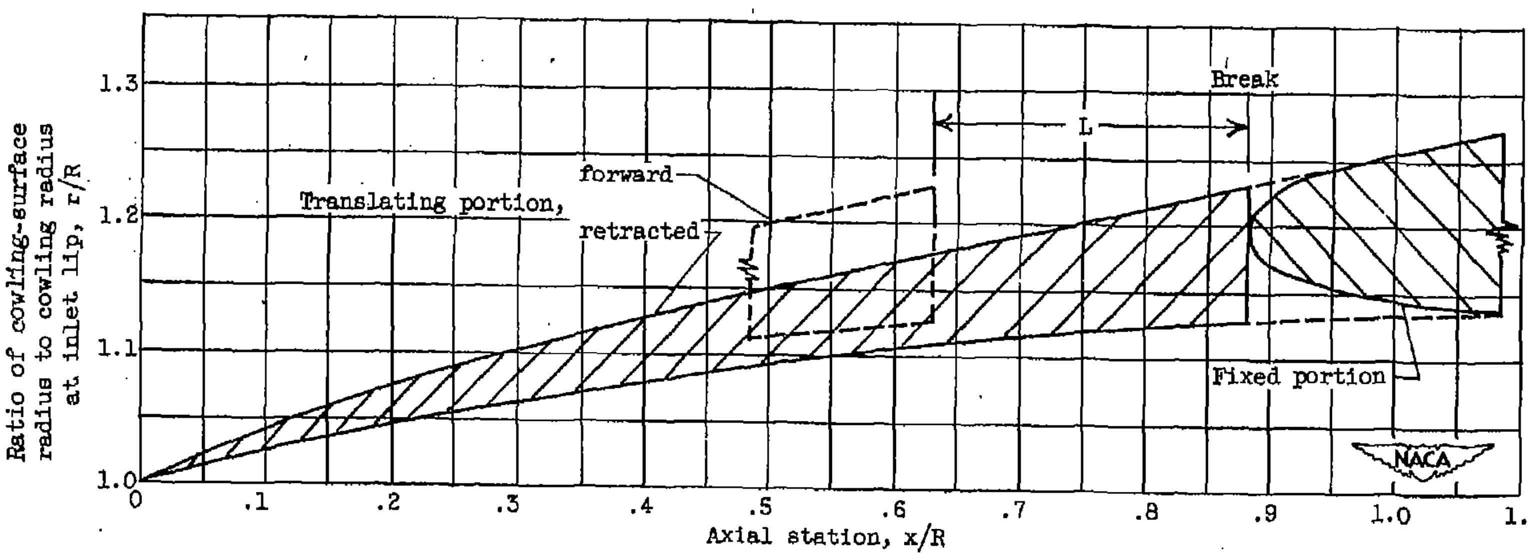


Figure 3. - Translating cowl profile and sketch of possible profile for use as mass-flow bypass.

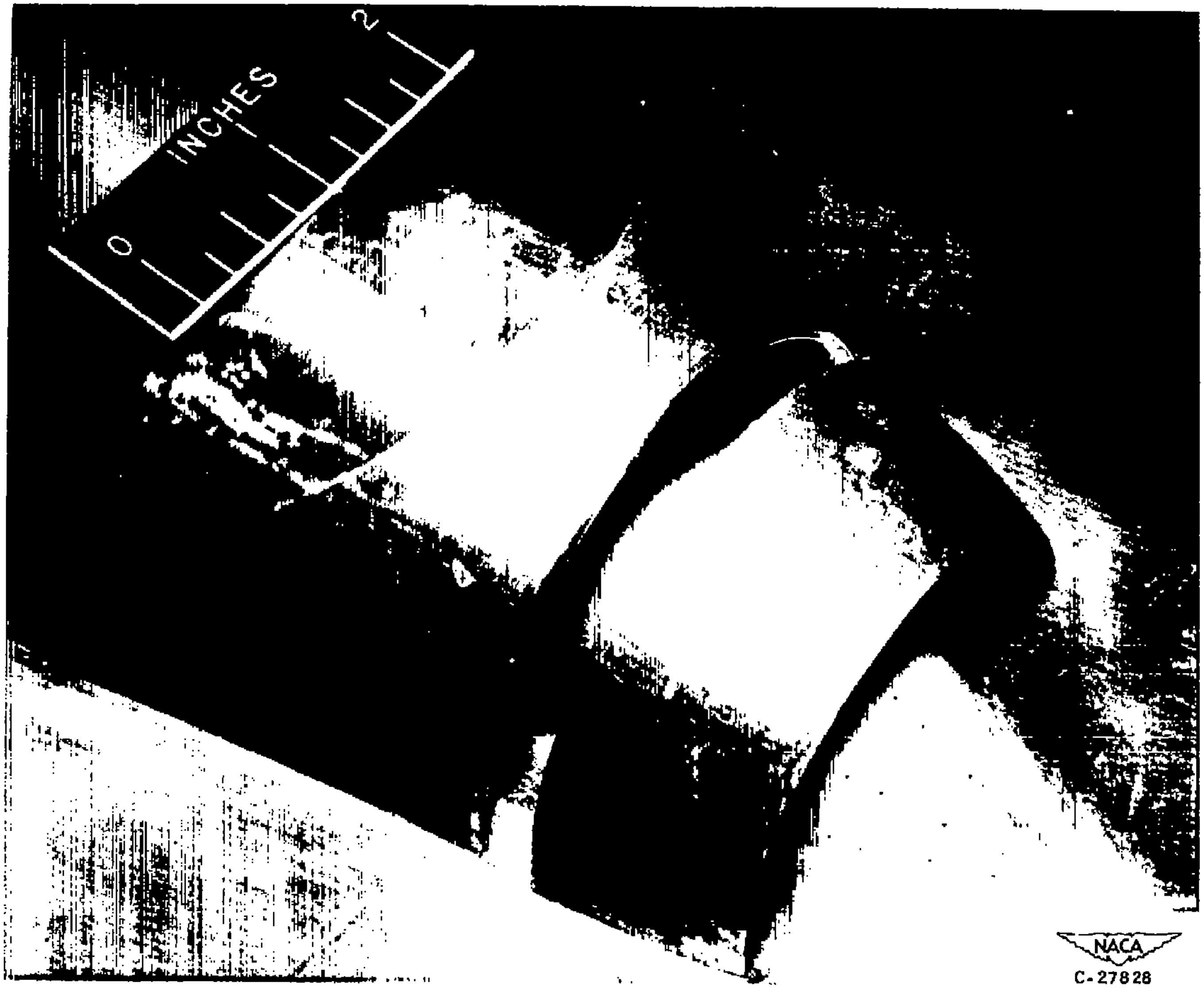


Figure 4. - Translating cowl open to cowl-position parameter L/R = 0.25.

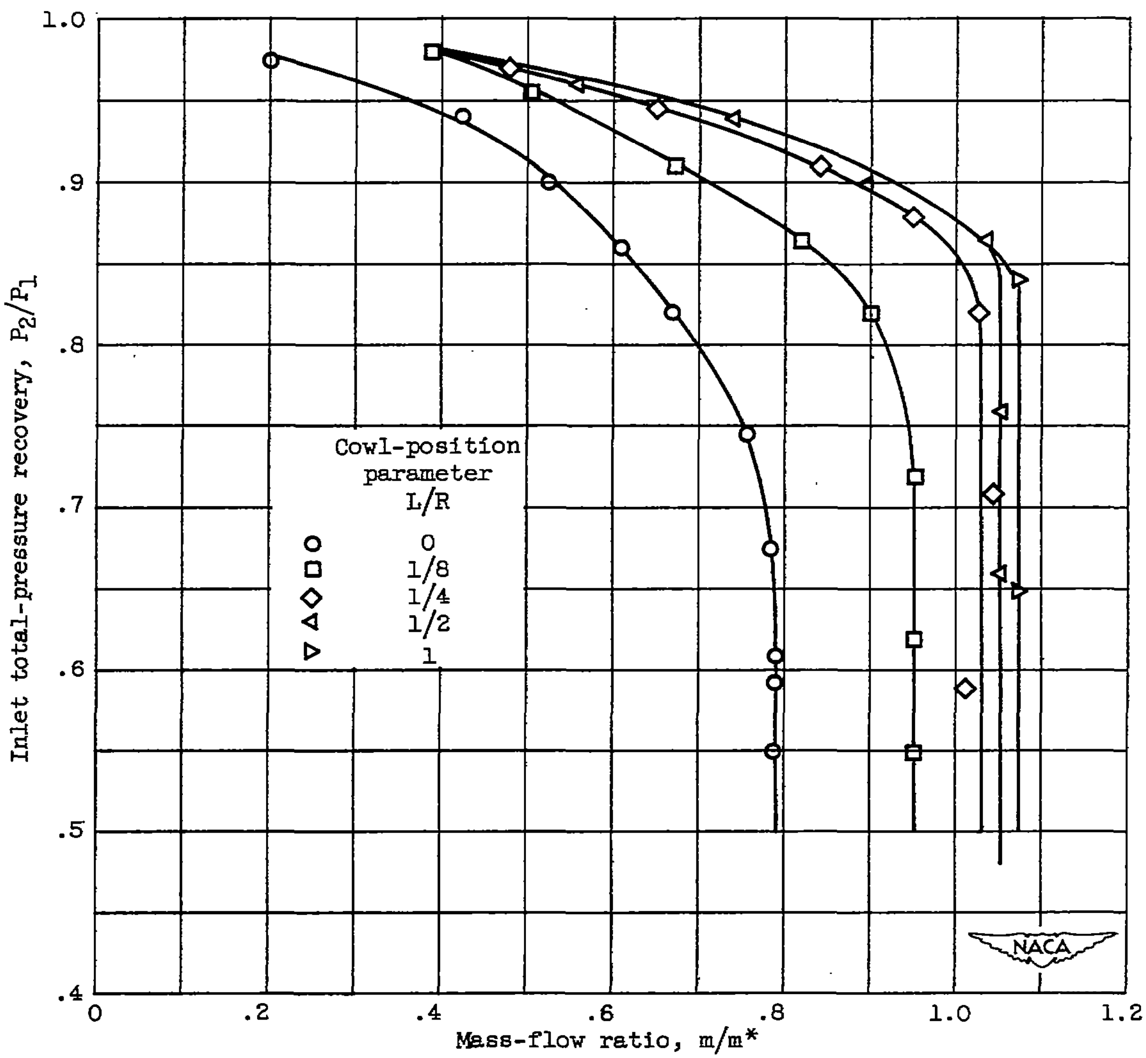


Figure 5. - Inlet total-pressure recovery in quiescent air as function of mass-flow ratio for range of cowl-position parameter, L/R.

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